A Foundational View on Roles in Conceptual Modeling

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Abstract. Roles remain elusive entities, although they are an integral part of socio-economic reality. This paper aims to examine roles in conceptual modeling from a foundational viewpoint. More specifically, we revisit Friedrich Steimann's well-known list of features of roles in light of the recently proposed 'three-facet theory' of roles that exploits a meta-ontological notion of grounding. We also hint at a strategy for formalizing an ontological module for generic role representation.

Keywords. role, conceptual modeling, relationship, context, grounding

1. Introduction

The socio-economic world is chock-a-block with roles (e.g., students) and the role concept is indispensable for rigorous modeling of multifarious social entities. For instance, it is nowadays fairly popular to model organizations (totally or partially) upon interrelations among roles in a number of different disciplines, ranging from multiagent systems [1,2] to enterprise modeling [3] and ontology research [4-6]. A careful analysis of roles is nonetheless so fraught with difficulties that it is still a controversial topic whether there is any single definition of role or not [7]. Even if "there is no single kind of roles, and no unique kind of entities on which roles depend" [8, p. 144], the challenge lies in providing a general characterization of multiple meanings of roles (see e.g., [9]).

The purpose of this short paper is to present a foundational perspective on roles in the context of conceptual modeling. Put concretely, we will reconsider Steimann's [10] list of features of the role concept that has been intensively discussed in (foundational) ontology research. Characteristic of our methodology is to leverage Toyoshima's [11] recent 'three-facet theory' of role, which says with a focus on ontology-driven conceptual modeling that there are three major interpretations of role in upper ontologies: a role specification, a role position, and a role potential. The work of the paper will enhance further development of the three-facet account, thereby contributing to a deeper understanding of roles from a modeling viewpoint. The rest of the paper is structured as follows. Section 2 presents an overview of the three-facet theory of role together with a more detailed explanation of meta-ontology and a meta-ontological notion of (fact-)grounding than Toyoshima [11] provides. Section 3 examines Steimann's 15 features of role in terms of the three facets of roles. Section 4 concludes the paper with a brief discussion on a possible way of designing a general role module.

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2. Three Facets of Roles

2.1. Grounding as a Meta-ontological Tool

Toyoshima [11] adopts a meta-ontological approach to roles. In foundational ontology research, there is an increasing practical interest in meta-ontology as a second-order inquiry into ontologies. Among meta-ontological concepts is a truthmaker [12,13]: something that 'makes true' (i.e., bears the 'truthmaking relation' towards) a proposition. The idea of truthmaker or truthmaking has been employed for the last decade to clarify complex ontological categories and relations. Examples include the formalization of states (of affairs) as truthmakers for propositions [14] and the conceptualization of properties, relations, and events in terms of 'truthmaking patterns' [15,16].

As a sibling notion of truthmaking, grounding [17-19] serves as a key conceptual tool in Toyoshima's [11] theorizing on roles, or especially its most orthodox version does: grounding as a primitive relation between facts [20,21]. For instance, the fact (say F_1) that a table exists is grounded in the fact (say F_2) that some subatomic particles are arranged table-wise; and informally, F_1 holds 'in virtue of' F_2. The theory of fact-grounding is usually coupled with the claim that the grounding relation at least entails explanation (see [19] for controversy over grounding and explanation). In the table example, F_2 grounds, and *ipso facto* explains F_1. Grounding is also so analogous with causation that one may sometimes call grounding 'ontological causation' [22].

Fact-grounding presupposes an ontology of facts. To keep things manageable, we leave aside the problematic character of facts (see e.g., [23]) and simply say that the term 'fact' is typically interpreted either as a true proposition or as a state of affairs. On the one hand, a proposition is standardly taken to play three major roles:

- The semantic content of a (declarative) sentence. E.g., two sentences "Snow is white" and "La neige est blanche" express the same proposition that snow is white.
- The object of various linguistic and cognitive attitudes ('propositional attitudes') including belief, assertion, and denial. E.g., when she sincerely utters "Snow is white," Mary bears the believing attitude towards the proposition that snow is white.
- The truthbearer: the bearer of truth-values (truth and falsehood). E.g., the proposition that snow is white is true.

On the other hand, a state of affairs is a concrete, non-lingo-cognitive portion of reality, but with a 'propositional structure': e.g., a state of affairs of snow being white [24]. A fact can be therefore described as something that 'holds' in reality in virtue of its propositional structure, irrespective of whether it is a true proposition or a state of affairs.

We can distinguish two kinds of grounding relations: full and partial grounding [21]. A plurality of facts $F_1, F_2, \ldots$ *fully ground* a fact G (symbolization: $F_1, F_2, \ldots \Rightarrow G$) when $F_1, F_2, \ldots$ ground G collectively and completely; and a fact F *partly grounds* a fact G (symbolization: $F \rightarrow G$) when F grounds G singly and partially. Partial grounding can be naturally defined in terms of full grounding: $F \rightarrow G$ if and only if there exist $F_1, F_2, \ldots$ such that $F, F_1, F_2, \ldots \Rightarrow G$. To illustrate them, let H and I be the fact that Japan is an eastern Asian country and the fact that Japan has a population of nearly 130 million, respectively; and let J the fact that Japan is an eastern Asian country with a population of nearly 130 million. Then, the following claims hold: $H \rightarrow J$, $I \rightarrow J$, and $H, I \Rightarrow J$.

We can also speak of some formal properties of grounding (whether full or partial) [21]. (i) Irreflexivity: no fact grounds itself. (ii) Transitivity: if a fact F_1 grounds a fact F_2, which in turn grounds a fact F_3, then F_1 grounds F_3. From (i) and (ii) follow straightforwardly the asymmetricity of grounding: if a fact F_1 grounds a fact F_2, then it is not the case that F_2 grounds F_1. To simplify the matter, we set aside a highly debatable topic of whether grounding is, in some sense, 'well-founded': whether it has no infinite descending chains or not (see e.g., [25] for details). Note that, unlike grounding, the truthmaking relation fails to preserve the property of chaining [21].

While examining some preceding accounts of roles, Toyoshima [11] hypothesizes that different theories of role might depend on different 'role choices' made by the theories: choices as to which is most fundamental among the 'three facets' of role (which he calls the 'role triad'), or its three main ontological interpretations, namely a role specification, a role position, and a role potential. To paraphrase it using fact-grounding simply, we introduce the notation '< >' to refer to facts: e.g., <Mary is a student of the ABC college>.

We also accept the widespread recognition that a role is a 'playable property': a property to be played by something ('player'). To be precise about the alleged playability of roles, we introduce Bird's [26] distinction between 'predicatory properties' and 'ontic properties'. Predicatory properties are properties that are defined by almost any predicate (e.g., "This apple *is green or not green*"). The predicatory usage of the term 'property' is an ontologically uncommitted, mere *façon de parler*: e.g., the property of being green or not green. Ontic properties are, by contrast, properties with a distinctive ontological role such as the property of being negative charged (which is vital in physics and chemistry). In this paper we speak of playing a role in the predicatory (but non-ontic) sense of the phrase.[2] The role-playing can be illustrated with Mary's studentness and fact-grounding as follows:

<Mary plays a student role> ⇒ <Mary is a student> (1)

Construed in light of fact-grounding, the core of Toyoshima's [11] argument is that three different role choices lead to three different facts each of which fully grounds <Mary plays a student role> and, by the transitivity of (full) grounding, <Mary is a student>.

2.2. Role Specification

One approach to Mary's studentness focuses on the deontic or normative dimension of her student role. Mary *must* gain admission to the ABC college in order to become an ABC-college student. To enjoy a full-time student status, she *needs* to register for a certain number of credit hours per semester. She is also *required* to defend her dissertation to obtain a doctoral degree from the ABC college. Mary's studentness is thus explicable in terms of the satisfaction of the constraints or conditions that are, so to speak, 'designated' by her student role.

This observation would lead to an analogy between a role and a specification. The ontological nature of a specification remains obscure, but Turner [28] maintains insightfully that a specification is something that has "correctness jurisdiction over an artefact" [28, p. 147]. By 'correctness jurisdiction' he means that the specification places

[2] For instance, our predicatory talk of role-playing must be sharply distinguished from the **has_role** (ontic, arguably) relation that is endorsed by an upper ontology Basic Formal Ontology (BFO) [27].

"empirical demands on the physical device" [28, p. 144]. If an artifact is not built to a certain specification, the artifact is defective with respect to that specification. Duncan [29] illustrates this point as follows: "For example, if I build a physical implementation of a stack and the device does not allow me to add and remove items from the top of the device, my device is defective relative to the specification of a stack" [29, pp. 16-17]. Quite importantly, Turner considers specifications as intentional: "Our intentional stance determines what we take to be the specification: something is a specification if we give it normal force over the construction of an artefact" [28, p. 147].

A role specification refers to a role that is understood by analogy with a specification and role-playing is interpreted as *meeting a role specification*. This amounts to the following full grounding:

<Mary meets a student role specification> ⇒ <Mary plays a student role> (2)

On this specification view of role, a player is to its role what an artifact is to its specification. In this respect, roles and artifacts are closely linked from a modeling perspective [30]. In the U.S., for instance, an aircraft has to meet the strict specification laid down by the Federal Aviation Administration (FAA). This means that an aircraft-like aggregate of mechanical parts is not an aircraft unless it is constructed exactly to the FAA specification. Likewise, the ABC college has drawn up intentionally its 'student role specification' (e.g., admission requirements), and Mary fails to be an ABC-college student unless she satisfies the ABC-student role specification.

2.3. Role Position

Another possibility for understanding Mary's studentness is based on the kind of situation in which Mary plays a student role. As an ABC-college student, Mary can use various facilities and enjoy educational opportunities (e.g., taking classes). Mary's studenteness may then consist in the fact that she locates herself in a specific 'sphere' or 'position' where she can do something role-related.

A role as conceptualized this way is analogous with a relative place [31]. Given the Newtonian conception of absolute space, both absolute places and relative places persist and may be occupied by various (material) objects at various times. Unlike absolute places (which are parts of absolute space that are independent of objects), relative places stand in fixed spatial relations with one or more objects (reference objects [31]). Examples include places in and around a ship whose reference object is the ship.

A role position means a role that is figured out by analogy to a relative place and role-playing is construed as *occupying a role position*. In other words:

<Mary occupies a student role position> ⇒ <Mary plays a student role> (3)

Seen from this positional perspective, roles stand in fixed 'conceptual' relations towards one or more entities, which may be sometimes called 'context' in the relevant literature [8,32]. In playing an ABC-student role, for example, Mary occupies the student role position that exists relative to the ABC college.

2.4. Role Potential

Yet another interpretation of Mary's studentness is modelled upon the ability of Mary to do something role-associated (which is sometimes informally called 'circumstantial possibility'). Since she is an ABC-college student, Mary *can* do many things (e.g., getting a student discount). She is *able* to acquire a degree from the ABC college, whereas non-ABC-college students are not. Mary's studentness would be explainable in terms of the potential that she bears in playing a student role.

A role potential designates a role that is thought of as a sort of circumstantial ability and role-playing is translated as *bearing a role potential*. That is to say:

$$\text{<Mary bears a student role potential>} \Rightarrow \text{ <Mary plays a student role>} \quad (4)$$

It is important to remark that, on this construal, a player has only to possess the role-related ability instead of demonstrating it actually. To remain an ABC-college student, Mary does not need to use any student discount; it is only necessary that she be able to do it.

A role potential may be easiest to understand in the role triad because it is intuitively grasped as a special kind of ability and avoids complications added by analogies with the complex notions such as a specification (in the case of a role specification) and a relative place (in the case of a role position). In contrast, a role potential should be treated with the utmost caution because it could be conflated with other apparently similar but different entities, viz. dispositions and functions.

3. Steimann's List of Features of Role

Steimann [10, pp. 86-87] identifies 15 features of roles that appear in the object-oriented and conceptual modeling literature, adding that "some conflict with others, and hence that there is no single definition of roles integrating all of them."[3] We will consider each feature of roles in Steimann's list in terms of the role triad. Note that we will not delve into details owing to spatial limitations.

3.1. "A role comes with its own properties and behaviour."

Although this is a "basic property" of roles according to Steimann, this statement is open to interpretation because so are the terms therein 'comes with' and 'its own'. On a charitable construal, the role triad would all have this quality; and this is true of a role potential most clearly because it *is* a kind of circumstantial property (ability) that can be manifested in the player's behaviors. On the other hand, it is less clear how a role specification and a role position possess their own properties and behaviors. They may be said to have this feature in virtue of their intimate connection with some role potential.

[3] For readability, we will henceforth cite Steimann [10, pp. 86-87] with no explicit reference to the literature unless otherwise specified.

3.2. "Roles depend on relationships."

Steimann says: "a role is meaningful only in the context of a relationship." This aspect of role would fit best with a role specification because it comes into being only when it relates to (precisely: inherits intentionality from) agents. In contrast, a role position would prefer the notion of context over relationships because it is based on the analogy of reference objects, which would be well conceptualized as a context (see e.g., [8,32]). Finally, a role potential has this feature in the sense that the player (e.g., Mary) is in some relationship (e.g., marriage). Note that the potential conception of role (i.e., a sort of ability) depends (existentially) on the player rather than relationships.

3.3. "An object may play different roles simultaneously."

It can be safely admitted that the role triad satisfy this desideratum. At the same time, the player can meet different role specifications, occupy different role positions, or bear different role potentials.

3.4. "An object may play the same role several times, simultaneously."

"This is an equally fundamental finding, a frequent example of which being an employee holding several employments. (…) each occurrence of the object in a role is associated with a different state." This trait of role is clearly observed in the cases of a role specification and a role potential. It varies with the situation how well the player meets a role specification; and a role performance ability can be manifested differently in different scenarios. By comparison, we could conceive that the player can occupy a role position with different degrees, but it is less intuitive what it really means to speak of the extent of, e.g., Mary's occupying a student role position.

3.5. "An object may acquire and abandon roles dynamically."

It would seem that all of the role triad have this aspect. It is well worth noting however that talk of the 'acquisition' and 'abandonment' of roles would match well a role potential because it conceptualizes a role as a kind of circumstantial *ability*, i.e., something to be acquired or abandoned literally.

3.6. "The sequence in which roles may be acquired and relinquished can be subject to restrictions."

"For example, a person can become a teaching assistant only after becoming a student." Although it is not hard to see that the role triad would all meet this criterion, the restriction on role-playing is observed most obviously in the case of a role specification because it is typically imposed intentionally by some agent. The qualification requirements of a teaching assistant are provided by the ABC college, for instance.

3.7. "Objects of unrelated types can play the same role."

Almeida et al. [3, p. 255] illustrate this feature as follows: "For example, both a person (John) and an organization (the University of Twente) can play the role of customer in

different business relationships." This property would be concordant with a role specification and a role position: John and the University of Twente can meet the same customer role specification and occupy the same customer role position. A role potential may not satisfy this desideratum straightforwardly, however, because John and the University of Twente must have different customer role potentials, although those abilities can be of the same type, i.e., the customer role type.

3.8. "Roles can play roles."

"This mirrors the condition that an employee (which is a role of a person) can be a project leader, which is then a role of the employee (but also another role of the person, although only indirectly)." As was alluded to in Section 3.6, each of the role triad has this property, and this is the case especially with a role specification.

3.9. "A role can be transferred from one object to another."

"It may be useful to let a concrete role dropped by one object be picked up by another, or even to specify the properties of a concrete role without naming a particular role player. For example, the salary of an open *position* may be specified independently of the person that will be employed" (our italicization added). The transferability of roles would mesh well with a role specification and a role position, which both remain neutral on its player. On the other hand, a role potential would not 'migrate' from player to player, and it would meet this criterion only in the sense of being inextricably linked with some role specification and/or some role position.

3.10. "The state of an object can be role-specific."

"The state of an object may vary depending on the role in which it is being addressed." Although it would match each of the role triad, this quality is indicated most clearly by a role position because it consists in taking role-playing to be located in a special kind of state or situation.

3.11. "Features of an object can be role-specific."

"Attributes and behaviour of an object may be overloaded on a by-role basis, i.e., different roles may declare the same features, but realize them differently. If an object plays several of these roles simultaneously, it responds according to the role in which it is being addressed." All the role triad would meet this standard; but as we implied in Section 3.1, role-specific properties and behaviors are shown most vividly by a role potential.

3.12. "Roles restrict access."

"When addressed in a certain role, features of the object itself (or of other roles of the object) remain invisible. This corresponds to an object having different perspectives, facets, or aspects." We agree with Almeida at al.'s [3] view that this is an implementation-oriented feature and omit to discuss it because it is outside the scope of our foundational investigation into roles in conceptual modeling.

3.13. "Different roles may share structure and behaviour."

"This usually means that role definitions inherit from each other (…), but sometimes also that the definitions of roles rely on features of the objects playing them (delegation) (…)." According to Almeida et al.'s [3, p. 255] illustration: "For example, both graduate students and undergraduate students have a student number, may register to courses, etc." We think that all the role triad would satisfy this desideratum of role nearly equally; but a role specification might capture this aspect more clearly because it clarifies well how roles are defined (intentionally).

3.14. "An object and its roles share identity."

Note that this feature and the next contradict each other. On our three-facet account of role, a role and its player could possibly have the same identity condition in the case of a role potential. As said in Section 3.2, a role potential depends existentially on its player. This means that the potential conception of role (e.g., Mary's student role) ceases to exist when its player (e.g., Mary) does, albeit not *vice versa*. In this regard, a role (potential) and its player may be said to have 'temporal identity' in common.

3.15. "An object and its roles have different identities."

In contrast, this opposite claim would fit well with a role specification and a role position because they would continue to exist even when its (possible) player perishes. This is a noteworthy feature from a modeling standpoint, as Steimann says: "This view (…) is a tribute to the so-called *counting problem*. It refers to the situation in which instances counted in their roles yield a greater number than the same instances counted by the objects playing the roles. For example, the number of passengers taking a certain means of transportation in one week may be greater than the number of individual persons traveling with that means during the same period." For space reasons our precise three-facet treatment of the counting problem has to be left for future work; but we point out that there is a growing consensus that it constitutes a workable solution to introduce qua-individuals [33,34] (aka role-holders [32]): roughly, new entities constituted of a player and properties that are relevant to role-playing (e.g., Mary-*qua*-student).

4. Discussion and Concluding Remarks

In short, we provided a foundational view on roles in conceptual modeling. More specifically, we revisited Steimann's [10] list of features in terms of the three-facet theory [11] of role. Further investigation is clearly warranted into each characteristics of roles and its relationship with the role triad. We conclude by discussing briefly a possible strategy for building an ontological module for generic role representation. There is an increasing demand for an integrated conception of roles, as evidenced by preceding attempts to elaborate the role data model [35,36]. Our grounding approach to roles might provide an important clue as to how to ontologize roles. As is indicated by Formulas (2)-(4), we have so far taken for granted that role-playing is fully explicable in terms of either of the role triad alone. To formalize a *general* role module may require however that

role-playing be well explained only by the role triad *as a whole*. This would be equivalent to the following full grounding of the fact about Mary's playing a student role:

<Mary meets a student role specification>,
<Mary occupies a student role position>,
<Mary bears a student role potential> ⇒ <Mary plays a student role> (5)

Note that, by definition, (5) entails the following partial grounding: <Mary meets a student role specification> (resp. <Mary occupies a student role position>, <Mary bears a student role potential>) → <Mary plays a student role>. It will be a promising line of research to deepen our grounding-based conceptualization of roles, for example by exploiting the logic of grounding [37-39]. Once a general formalization of roles is available, further work includes (i) its specialization against a specific ontological background (see e.g., [40] based on the BFO upper ontology) and (ii) its application to an ontological analysis of specific roles such as social roles [41] and thematic roles [42] together with a domain-specific practical application (see e.g., [43,44]).

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